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DISPLACEMENT OF LARVAL FISH BY BRUCE NGS "A" DISCHARGE

Report No 87-7-K
David W. Rodgers
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

The potential for displacement of larval fish by the thermal discharge of Bruce NGS "A" was investigated by tracking drift tubes released near the discharge plume and sampling larval fish along the path followed by the drift tube. Drift paths were strongly influenced by changes in longshore lake currents which, in turn, were largely determined by prevailing winds. Under relatively constant winds to the north, north-east, the the drift tubes were carried by the longshore current into the Bruce NGS "A" thermal discharge plume and displaced up to 1 km offshore. Under light and variable wind conditions, the drift tubes were carried by the longshore current into the region of the thermal discharge plume but then moved relatively little and remained stationary at the edge of the plume.

Alewife dominated the larval fish samples and comprised approximately 62% of the total larval fish collected. Gizzard shad, johnny darter and trout perch were also significant species. The densities of larval fish within the thermal discharge were significantly lower than densities of larval fish in the zone of mixing of the thermal discharge plume or in the nearshore zone before the thermal discharge. The densities of fish in these latter regions were not significantly different.

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EXECUTIVE SUMMARY

DISPLACEMENT OF LARVAL FISH BY BRUCE NGS "A" DISCHARGE

David W. Rodgers
Biologist
Biological Research Section
Chemical Research Department

At the request of Design and Development Division, the potential for displacement of larval fish by the thermal discharge of Bruce NGS "A" was investigated by tracking drift tubes released near the discharge plume and sampling larval fish along the path followed by the drift tube. As part of the Once Through Cooling program, the information obtained in this and related earlier studies will be used in the development of a general model to predict the displacement of larval fish by the thermal discharge of nuclear and fossil generating stations.

Drift paths were strongly influenced by changes in longshore lake currents which, in turn, were largely determined by prevailing winds. Under constant winds of 10-20 km/h to the north, northeast, drift tubes were carried by the longshore current into the Bruce NGS "A" thermal discharge plume and displaced up to 1 km offshore. Under light and variable wind conditions, the drift tubes were carried by the longshore current into the region of the thermal discharge plume but then moved relatively little and remained stationary at the edge of the plume.

Alewife dominated the larval fish samples and comprised approximately 62% of the total larval fish collected. Gizzard shad, johnny darter and trout perch were also significant species. The densities of larval fish within the thermal discharge were significantly lower than densities of larval fish in either the nearshore zone before the thermal discharge or the zone where the

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thermal discharge plume mixed with lake water. Larval densities in these last two regions were not significantly different. The observed densities differ from those predicted by a preliminary computer model, which suggested a dilution of larvae in the discharge mixing zone. The differences between predicted and observed larval densities may derive from the model's simplistic assumption that larvae are released from a single point source.

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To: Dr. W.R. Effer
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DISPLACEMENT OF LARVAL FISH BY BRUCE NGS "A" DISCHARGE

INTRODUCTION

As part of the Once Through Cooling program, Design and Development Division is developing a general model to assess the potential for displacement of larval fish by the thermal discharge of operating generating stations. A preliminary model indicated that the thermal discharge of Bruce "A" NGS could significantly displace larval fish under certain currents (Raithby 1984). In particular, during a northeast current, the Bruce NGS "A" discharge could dilute concentrations of fish released close to shore.

At the request of Environmental Studies and Assessments (ES&A), Design and Development Division, the Biological Research Section undertook a two year study of the potential for the thermal discharge of Bruce "A" NGS to displace larval fish. The first phase of this study, which was conducted in 1984, determined the path followed by small positively buoyant drift tubes as they were carried by the longshore currents into the Bruce "A" discharge (Ontario Hydro Research Division Report No 85-40-K). In the present study, both the movement of the drift tubes and the densities of larval fish along the path followed by drift tubes were investigated. The information obtained in this and related earlier studies will be employed in the development of a general model to predict the displacement of larval fish by the thermal discharge of nuclear and fossil generating stations.

EXPERIMENTAL PROCEDURES

Sampling was conducted in Lake Huron near the thermal discharge of Bruce "A" NGS from July 17 to August 14 1985, a period which was expected to coincide with highest densities of larval alewife off the Bruce Nuclear Power Development (Ontario Hydro Research Division Report No 84-47-K). On each sampling day, the procedure was divided into two distinct components:

1) The release and tracking of a drift tube as it was carried by the longshore current from 'upstream' of the Bruce NGS "A" discharge into the discharge.

2) The sampling of larval fish from locations along the path followed by the drift tube.

As preliminary sampling indicated that few larval fish were collected in surface waters during the day, drift paths were determined at dusk (18:00-20:00h) and larval fish collected at night (after 20:30h) (see also Pope 1984).

The drift tubes consisted of a small FM radio transmitter and mercury battery enclosed in a sealed plastic tube (10 cm long, 2.5 cm inside diameter). The density of the drift tube was adjusted before sealing so that the tube was positively buoyant, with the top of the tube approximately flush with the water surface when the tube was immersed in water. Additional details concerning the construction of the drift tubes and methods used in tracking the tubes once released are described elsewhere (Ontario Hydro Research Division Report No 85-40-K).

At approximately 18:00 h of each sampling day, the drift tube was released from 'upstream' of the thermal discharge along the 3 m depth contour, approximately 200 m offshore. The drift tube was then tracked for the next 1.5 h as it was carried by the longshore current and discharge. Throughout the period of drift, the position of the drift tube was regularly fixed using a LORAN receiver. LORAN coordinates were matched with those of a LORAN C grid map of the area which had been established in the earlier study (Ontario Hydro Research Division Report No 85-40-K). The path followed by the drift tube was also marked by setting four anchored light buoys at intervals during the drift, normally 10, 35, 60, 85 min.

Following the determination of drift path, the boat returned to the the anchored light buoys and larval fish were sampled at the buoy and at two points which were approximately 100 m from the buoy at each side of a line perpendicular to the direction of travel of the drift tube. Larval fish were collected from surface waters at a depth of 0.5-1 m using a boat mounted pump/net system (OHRDR 85-59-K). The pump/net system filtered approximately 2,800 L/min, and thus passed 42 m^3 of lake water in the 15 min sampling interval. Weather permitting, the above sampling sequence was repeated for each anchored buoy. The order of sampling was alternated between sampling dates, with the buoys sampled in ascending order of release (first through fourth) on one day and descending order of release on the next day. Samples were preserved in formalin (approximately 5%) and ichthyoplankton were subsequently sorted, enumerated, measured and identified.

Records of the ambient air temperature, wind speed and direction on each sampling day at the 10 m level of the Environment Canada station at Bruce NGS "A" were provided by the Geotechnical and Hydraulic Engineering Department, Design and Development Division - Generation. Operations at Bruce NGS "A" were consistent on all sampling dates, with average discharge water flows of 164-166 m^3/s.

In addition to sampling along the drift path, an offshore transect northwest of the thermal discharge was sampled to define changes in density of larval fish with distance offshore. Duplicate, 15 min. samples were collected along a transect perpendicular to the shoreline from anchored spars which were located approximately 100, 500, 1000 and 1500 m offshore (at depths of approximately 3, 7, 10 and 10 m respectively). Densities of larval fish in the discharge channel of Bruce NGS "A" were provided by Mr. S. McKinley of the Biological Research Section from a concurrent study of entrainment of larval fish by Bruce NGS "A" (Ontario Hydro Research Division Report No 86-190-K).

The LORAN C grid map of the area off the Bruce NGS "A" discharge established in the previous study (Ontario Hydro Research Division Report No 85-40-K) was transcribed and digitized using the Digital Paintbrush System (Jandel Scientific, Bridgeway, California) program and a Micro DIGI-PAD (GFTO Corporation, Rockville, Maryland). The path followed by the drift tube was then located on the reference grid map and the distance traveled by the drift tube estimated using the Measurement/Estimate Program of the Digital Paintbrush System.

On the basis of the observed drift path and field notes larval fish samples from the drift collections were classified as:

1) Nearshore lake samples which were collected from locations before the drift tube reached the discharge plume.

2) Mixing zone samples which were collected in the area where the discharge plume mixed with nearshore lake water.

These collections were also compared with collections of larval fish in the discharge channel. Results were analyzed by analysis of variance, with larval densities transformed using the square root transformation. This transform was employed as an examination of residual and normal probability plots indicated that it was required to comply with assumptions of normality and equality of variance inherent in the analysis of variance. (Steel and Torrie 1980). If the F was significant ($p<0.05$) in the analysis of variance, means were compared using the LSD method.

RESULTS AND DISCUSSION

A) Drift Tube Movements

On 4 of the 6 sampling days (August 7,8,13 and 14), the prevailing winds during the period from 12:00 to 18:00 h were out of the south west and blew in a north, north-easterly direction at speeds of 10-20 km/h (Table 1). On August 9, light winds of 5-

TABLE 1

TEMPERATURE, WIND SPEED AND DIRECTION, AUGUST 7-14, 1985
ENVIRONMENT CANADA (BRUCE NGS "A", 10m TOWER)

		TIME (h)												
		12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
AUGUST 7														
	AIR TEMP (C)	22.6	23.9	23.3	23.5	24.6	24.2	24.2	24.0	22.2	20.5	19.2	19.3	18.8
	WIND SPEED (Km/Hr)	19	21	22	21	22	21	19	14	12	10	2	6	4
	WIND DIRECTION (DEGREES)*	204	209	206	211	209	209	209	200	206	242	296	4	342
AUGUST 8														
	AIR TEMP (C)	23.5	23.5	23.4	23.9	24.3	24.7	23.3	21.5	20.7	19.7	20.0	19.9	19.4
	WIND SPEED (Km/Hr)	17	18	16	14	10	8	6	4	1	3	7.0	5.0	5.0
	WIND DIRECTION (DEGREES)*	225	226	230	234	242	253	287	342	360	125	115	140	155
AUGUST 9														
	AIR TEMP (C)	24.2	25.5	25.9	26.5	25.2	24.6	27.3	27.9	24.6	24.1	23.4	22.7	22.5
	WIND SPEED (Km/Hr)	12	10	11	3	6	8	9	7	NA	5	7	6	8
	WIND DIRECTION (DEGREES)*	246	243	244	291	21	36	46	49	NA	122	119	122	158
AUGUST 12														
	AIR TEMP (C)	22.0	23.8	23.2	20.2	20.3	20.2	20.1	20.6	20.3	20.0	18.7	17.7	16.6
	WIND SPEED (Km/Hr)	8	6	9	11	11	12	9	6	7	10	10	8	10
	WIND DIRECTION (DEGREES)*	129	162	319	332	350	17	31	42	93	116	116	146	141
AUGUST 13														
	AIR TEMP (C)	23.0	23.8	22.1	23.1	24.3	24.3	24.2	24.1	22.8	22.5	21.8	21.6	21.6
	WIND SPEED (Km/Hr)	21	22	20	16	18	16	17	16	15	21	18	20	19
	WIND DIRECTION (DEGREES)*	200	206	224	225	226	227	223	219	212	221	219	223	214
AUGUST 14														
	AIR TEMP (C)	24.6	25.0	24.9	23.9	22.8	23.1	23.1	22.3	22.0	21.6	21.2	21.3	21.3
	WIND SPEED (Km/Hr)	19	20	19	18	18	17	15	15	15	9	7	5	7
	WIND DIRECTION (DEGREES)*	216	216	208	209	195	198	199	200	208	199	191	205	221

* Direction wind is from

10 km/h blew in a east, north-easterly direction from 12:00 to 15:00 h and then shifted to south, south-west from 16:00 to 20:00 h. Winds were also variable on August 12; blowing towards the north to north-west from 12:00-14:00 h (8-11 km/h), then shifting towards the south to south-west from 14:00-20:00 h (7-12 km/h). Maximum ambient air temperatures on all days ranged from 24-28 ^{o}C with minimum temperatures of 17-22 ^{o}C.

On the 4 days when prevailing winds blew towards the north to north-east, the longshore current carried the drift tube in an east, north-easterly direction towards the thermal discharge (Figure 1 - detailed records of the path followed by the drift tube on each day are given in Appendix 1). Average drift velocities before reaching the plume were in the order of 10 cm/s. The behavior of the drift tube on reaching the area of the thermal discharge differed among sampling days. On August 7 and 14, the drift tube moved rapidly northward on reaching the discharge plume and was carried approximately 1 km offshore over the tracking period. Drift paths on August 8 and 13 were generally similar to August 7 and 14, but the total distance the drift tube was displaced by the discharge plume was less, and on August 8 the longshore current carried the drift tube further inshore than on other days. Drift velocities within the zone of influence of the thermal discharge varied considerably within and between tests, with maximal rates of displacement in the order of 45 cm/s.

In contrast, under variable wind conditions on August 9, the drift tube was carried east by the longshore current but remained essentially stationary on reaching the discharge plume. Similarly, on August 12, again under variable winds, the drift tube was carried west by the longshore current towards the discharge plume at speeds of 10-15 cm/s, but on reaching the discharge plume the drift tube was largely stationary.

The drift trajectories and velocities observed on the four days with constant winds from the south,south-west were generally similar to the paths reported in the earlier tests for drift tubes released upstream of the discharge on the 3 m contour (Ontario Hydro Research Division Report No 85-40-K). The essentially stationary drift path observed at the edge of the discharge plume under variable wind conditions (August 9 and 12) has not been reported previously. These new observations indicate that drift paths are strongly influenced by changes in longshore lake currents which in turn are largely determined by prevailing wind direction. These findings are consistent with those of the previous study (Ontario Hydro Research Division Report No 85-40-K).

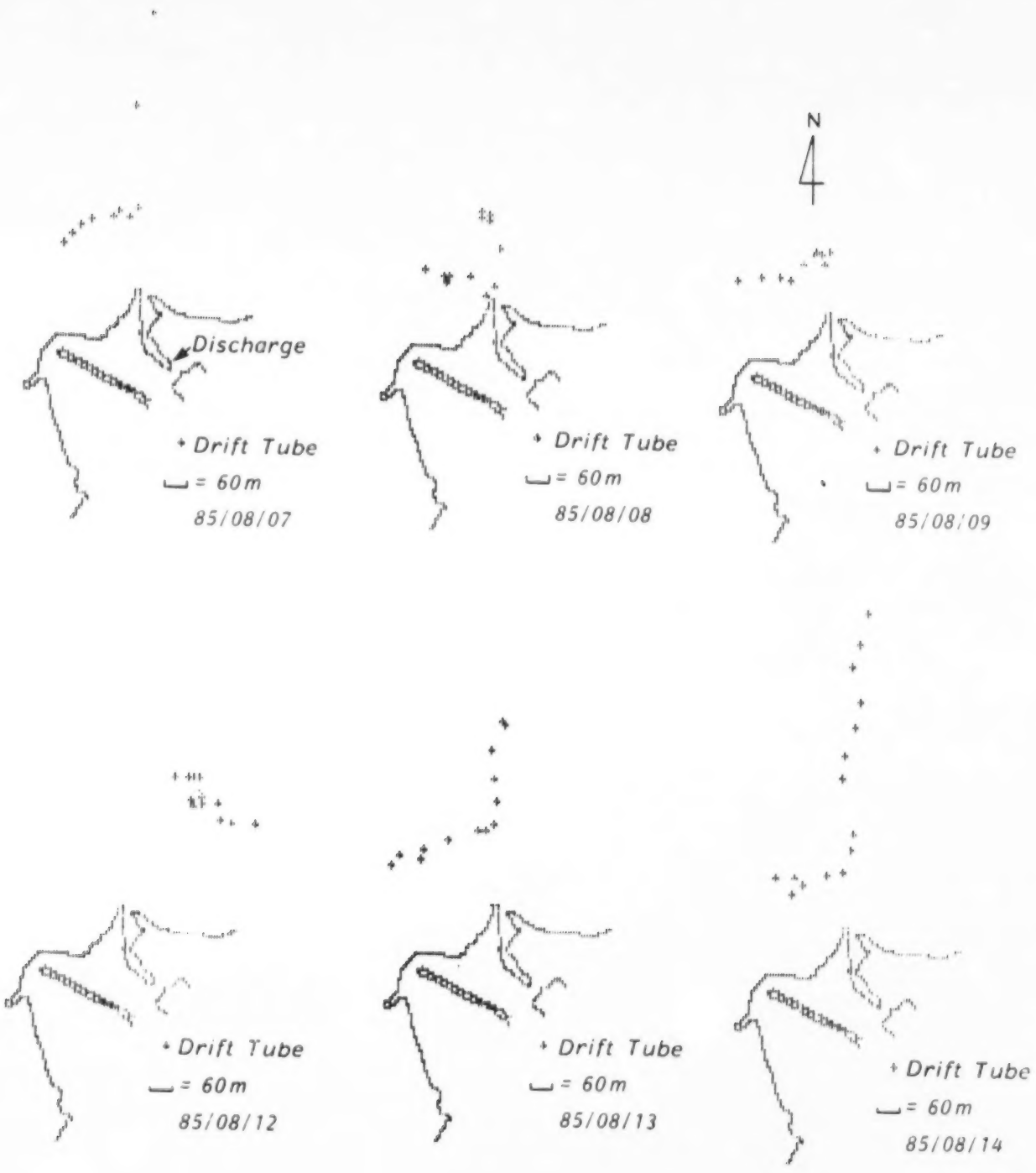

FIGURE 1
TRAJECTORIES OF DRIFT TUBES ON INDICATED DATES

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B) Larval Fish Collections

A total of 331 larval fish were collected, with 235 collected in drift samples, an additional 73 collected in transect samples and 25 collected in discharge samples. (Detailed records of samples are contained in Appendix 2.) Alewife, Alosa pseudoharengus, dominated the samples and comprised 62% of all larval fish collected. Other fish which were important in the samples were gizzard shad, Dorosoma cepedianum, which constituted about 17% of the total number of fish collected, johnny darter, Etheostoma nigrum, (11% of the total number of fish collected) and trout perch, Percopsis omiscomaycus, (6% of the total number of fish collected). The marked dominance of larval alewife in the larval fish collections is consistent with the patterns seen in samples of larval fish collected in the area of the Bruce Nuclear Power Development (BNDP) in previous years (Ontario Hydro Research Division Report No 84-47-K). In contrast gizzard shad, johnny darter and trout perch each comprised less than 2% of larval fish collected at BNDP from May through September of 1979-1981. The importance of gizzard shad, johnny darter and trout perch in the present collections likely resulted from local concentrations of these fish when the samples were collected.

The numbers of larval fish collected in individual samples varied over a wide range, with estimated densities ranging from 0 to 429 larvae/ 1000 m^3. Among the transect samples, there was a general trend for densities of larval fish to be higher in nearshore samples (Table 2), with the significantly greater densities of larval fish at the 100 m spar than at the 1500 and 500 m spars. This trend was largely the result of the high numbers of larval trout perch and johnny darter collected at the 100 m spar, however and the densities of larval alewife and smelt did not vary significantly among spars. These results are consistent with an earlier survey of potential sites for generating stations on Lakes Erie, Huron and Ontario (Pope 1984), where factors such as currents, depth and substrate were more important than distance from shore in determining densities of larval fish.

The average densities of larval fish in the discharge samples (49 $\pm$ 18 larvae/ 1000 m^3 mean $\pm$ SE, n = 12) were significantly lower than the mean densities of larval fish in either nearshore lake samples (124 $\pm$ 24 larvae/ 1000 m^3, n = 24) or mixing zone samples (87 $\pm$ 18 larvae/ 1000 m^3, n = 30) (Table 3). When only days with a north, north-east wind (Aug 7,8,13 and 14) were analyzed separately, the results were generally similar to those obtained for all sampling dates. Although the densities of larval fish in nearshore lake samples were greater than densities of larval fish in the mixing zone, these differences were not statistically significant. The lack of significant differences in densities of larval fish between nearshore lake and mixing zones may indicate either that the volume of the Bruce NGS "A"

Table 2

Average densities of larval fish (larvae/ 1000 m^3) in transect samples of July 17, July 23 and August 14,1985. (Mean + SE)

	All Fish Larvae	Alewife and Smelt
100m spar	163 ± 47	68 ± 32
500m spar	20 ± 11	20 ± 11
1000m spar	100 ± 36	100 ± 36
1500m spar	32 ± 21	32 ± 21

Table 3

Average densities of larval fish (larvae/ 1000 m^3) in Lake, Mixing Zone and Discharge samples off Bruce NGS "A" (Mean + SE with number of samples in parentheses)

	Lake	Mixing Zone	Discharge
August 7,1985	143 (1)	92.6±24.0 (9)	—
August 8,1985	198±46 (6)	95.2 (1)	143±36 (3)
August 9,1985	79.4±35.1 (6)	171±63 (5)	—
August 11,1985	—	—	7.9±7.9 (3)
August 12,1985	254±88 (3)	143±95 (3)	15.9±7.9 (3)
August 13,1985	52.4±25.4 (5)	59.5±20.2 (6)	31.7±7.9 (3)
August 14,1985	47.6±25.5 (3)	7.9±5.0 (6)	—

discharge is insufficient to significantly change densities of larval fish or that larval fish are retained in the mixing zone. This lack of dilution in the densities of larval fish in the discharge mixing zone differs from the preliminary computer model of Raithby (1984), which suggested that under a northeast current, the densities of larval fish released close to shore would be diluted by the Bruce NGS "A" discharge. The differences between predicted and observed results may derive from the model's simplistic assumption that larvae are released from a single point source. Future models should consider the consequences of diffuse release of larval fish 'upstream' of the Bruce NGS "A" discharge. The situation is further complicated as larval fish could occupy the entire water column but only surface samples were collected in the present study. Additional studies would be required to determine if the present results apply to the whole water column.

SUMMARY AND CONCLUSIONS

1) Drift paths were strongly influenced by changes in longshore lake currents which, in turn, were largely determined by prevailing winds. Under constant north, north-east winds of 10-20 km/h, drift tubes were carried by the longshore current into the Bruce NGS "A" thermal discharge plume and displaced up to 1 km offshore. Under light and variable wind conditions, the drift tubes were carried by the longshore current into the region of the thermal discharge plume but then moved relatively little and remained stationary at the edge of the plume.

2) Alewife dominated larval fish samples and comprised approximately 62% of the total larval fish collected. Other important fish species collected were gizzard shad, johnny darter and trout perch.

3) The densities of larval fish collected within the thermal discharge were significantly lower than densities of larval fish collected in either the nearshore zone before the thermal discharge or the zone where the thermal discharge plume mixed with lake water. The densities of fish collected in these last two regions were not significantly different. In contrast, the computer model of Raithby (1984), which suggested that under a northeast current, the densities of larval fish released close to shore would be diluted by the Bruce NGS "A" discharge. The differences between predicted and observed larval densities may derive from the model's simplistic assumption that larvae are released from a single point source.

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APPENDIX 1 - A

Drift tube record - August 7, 1985

Time (hr:min)	Loran Grid (see reference map)		Distance (m)	Comments
0:00	30250.5	49103.2		Release of tube
0:05	30250.3	49103.1	29.5	
0:10	30350.1	49103.0	25.1	First buoy set
0:15	30249.9	49102.9	26.8	
0:20	30249.6	49102.9	51.3	
0:25	30249.4	49102.8	16.2	
0:30	30249.2	49102.9	31.1	Second buoy set
0:35	30249.0	49102.8	31.0	Drift tube in discharge plume
	Tube lost for approximately 50 min			
1:25	30248.8	49101.3	257.3	Third buoy set
	Tube lost for approximately 20 min			
1:45	30248.3	49099.9	235.1	Fourth buoy set

APPENDIX 1 - B

Drift tube record - August 8, 1985

Time (hr:min)	Loran Grid (see reference map)		Distance (m)	Comments
0:00	30250.4	49103.5		Release of tube
0:11	30350.0	49103.6	67.1	First buoy set
0:25	30250.0	49103.7	26.8	
0:35	30249.9	49103.6	27.4	Second buoy set
0:45	30249.5	49103.7	96.4	
0:55	30249.3	49103.9	54.1	Drift tube in discharge plume
1:00	30249.1	49103.8	40.7	Third buoy set
1:07	30248.9	49103.2	97.5	
1:11	30249.0	49102.8	112.5	
1:16	30249.2	49102.8	28.1	
1:20	30249.1	49102.7	10.1	
1:25	30249.2	49102.7	10.4	Fourth buoy set

APPENDIX 1 - C

Drift tube record - August 9, 1985

Time (hr:min)	Loran Grid (see reference map)		Distance (m)	Comments
0:00	30250.8	49103.4		Release of tube
0:05	30250.4	49103.4	77.9	
0:10	30350.0	49103.4	56.3	First buoy set
0:15	30249.8	49103.4	39.9	
0:25	30249.6	49103.2	64.9	
0:35	30249.4	49103.2	39.7	Second buoy set
0:45	30249.1	49103.2	24.5	
1:00	30249.0	49103.2	36.0	Third buoy set
1:10	30249.2	49103.2	35.7	
1:25	30249.1	49103.3	33.6	Fourth buoy set

APPENDIX 1 - D

Drift tube record - August 12, 1985

Time (hr:min)	Loran Grid (see reference map)		Distance (m)	Comments
0:00	30246.5	49103.0		Release of tube
0:05	30246.9	49103.0	58.0	
0:10	30347.1	49102.9	26.5	First buoy set
0:15	30247.1	49102.7	40.5	
0:25	30247.4	49102.7	63.4	
0:30	30247.4	49102.6	21.4	
0:35	30247.5	49102.5	24.9	Second buoy set
0:40	30247.6	49102.6	16.4	
0:51	30247.6	49102.5	23.2	
1:00	30247.4	49102.3	35.5	Third buoy set
1:10	30247.5	49102.3	10.1	
1:18	30247.6	49102.3	15.6	
1:25	30247.8	49102.3	30.4	Fourth buoy set

APPENDIX 1 - E

Drift tube record - August 13, 1985

Time (hr:min)	Loran Grid (see reference map)		Distance (m)	Comments
0:00	30251.1	49103.3		Release of tube
0:07	30250.9	49103.1	27.2	
0:10	30350.6	49103.2	54.2	First buoy set
0:15	30250.5	49103.1	23.8	
0:20	30249.9	49103.0	64.3	
0:25	30249.4	49102.9	73.5	
0:30	30249.4	49102.9	0.0	
0:35	30249.2	49102.9	20.0	Second buoy set
0:40	30249.0	49102.8	25.4	
0:50	30248.9	49102.5	48.8	
	Drift tube reached discharge plume			
1:00	30248.9	49102.2	62.0	Third buoy set
1:10	30248.8	49101.8	66.0	
1:19	30248.6	49101.5	70.3	
1:25	30248.6	49101.4	18.9	Fourth buoy set

APPENDIX 1 - F

Drift tube record - August 14, 1985

Time (hr:min)	Loran Grid (see reference map)		Distance (m)	Comments
0:00	30250.4	49103.2		Release of tube
0:05	30250.1	49103.4	53.2	
0:10	30350.0	49103.2	41.9	First buoy set
0:15	30249.9	49103.3	23.6	
0:20	30249.5	49103.2	61.4	
0:28	30249.1	49103.2	43.4	
Drift tube reached discharge plume - lost approximately 10 min				
0:40	30248.9	49102.9	60.3	Second buoy set
0:45	30248.8	49102.7	38.7	
0:50	30248.8	49101.9	134.5	
0:55	30248.7	49101.6	54.3	
1:02	30248.5	49101.2	72.3	Third buoy set
1:10	30248.3	49100.8	66.9	
1:15	30248.3	49100.3	84.3	
1:20	30248.1	49100.0	61.2	
1:25	30247.8	49099.6	79.8	Fourth buoy set

APPENDIX 2 - A

Fish Capture Data - Transect Sample 85/07/17 - Night

Label #	Location (Loran grid)	Larval fish collected (size in mm)	Density (larvae/1000 m^3)
33551	100 m spar (30251.8/49104.0)	8 johnny darter 1 alewife	190 24 Total 214
33552	100 m spar (30251.8/49104.0)	6 johnny darter 1 alewife	143 24 Total 167
33553	500 m spar (30252.8/49102.3)	0	----
31407	1000 m spar (30254.0/49100.4)	1 smelt (10)	24
33558	1500 m spar (30255.2/49098.7)	1 smelt (12)	24

APPENDIX 2 - B

Fish Capture Data - Transect Sample 85/07/18 - Day

Label #	Location (Loran grid)	Larval fish collected (size in mm)	Density (larvae/1000 m^3)
33577	100 m spar (30251.8/49104.0)	0	----
33578	100 m spar (30251.8/49104.0)	0	----
33579	500 m spar (30252.8/49102.3)	0	----
33580	500 m spar (30252.8/49102.3)	0	----
33581	1000 m spar (30254.0/49100.4)	0	----
33582	1000 m spar (30254.0/49100.4)	0	----
33583	1500 m spar (30255.2/49098.7)	0	----
33584	1500 m spar (30255.2/49100.4)	0	----

APPENDIX 2 - C

Fish Capture Data - Transect Sample 85/07/23 - Night

Label #	Location (Loran grid)	Larval fish collected (size in mm)	Density (larvae/1000 m^3)
31410	100 m spar (30251.8/49104.0)	6 alewife (4-6) 7 trout perch (5-7)	143 167 Total 310
31411	100 m spar (30251.8/49104.0)	5 alewife (3-6) 1 trout perch (7)	119 24 Total 143
31407	500 m spar (30252.8/49102.3)	1 smelt (14)	24
31408	500 m spar (30252.8/49102.3)	2 alewife (4,5,6)	48
31404	1000 m spar (30254.0/49100.4)	7 alewife (3 - all)	167
31409	1000 m spar (30254.0/49100.4)	6 alewife (5 - all)	143
31405	1500 m spar (30254.0/49100.4)	3 alewife (3,4,5)	71
31406	1500 m spar (30254.0/49100.4)	3 alewife (3,6,6)	71

APPENDIX 2 - D

Fish Capture Data - Transect Sample 85/08/14 - Night

Label #	Location (Loran grid)	Larval fish collected (size in mm)	Density (larvae/1000 m^3)
33819	100 m spar (30251.8/49104.0)	1 alewife (13) 1 johnny darter (6) 1 unidentified piece	24 24 24 Total 72
31411	100 m spar (30251.8/49104.0)	2 alewife (21) 1 trout perch (6)	48 24 Total 72
33817	500 m spar (30252.8/49102.3)	1 alewife	24
33818	500 m spar (30252.8/49102.3)	1 alewife	24
33815	1000 m spar (30254.0/49100.4)	0	----
33816	1000 m spar (30254.0/49100.4)	7 alewife	167
33813	1500 m spar (30254.0/49100.4)	0	----
33814	1500 m spar (30254.0/49100.4)	0	----

APPENDIX 2 - E

Fish) Capture Data - Drift Sample 85/08/07 - Night

Label #	Location (Loran grid)	Larval fish collected (length in mm)	Density (larvae/1000 m^3)
33614	1st buoy-center (30250.1/49103.1) -Lake-	6 alewife	143
33613	2nd buoy-right (30249.0/49102.9) Mixing zone	5 alewife 1 johnny darter	119 24 Total 143
33612	2nd buoy-left (30249.4/49102.8) Mixing zone	8 johnny darter (2x4,6x5)	190
33611	2nd buoy-center (30249.1/49102.8) Mixing zone	2 johnny darter (5)	48
33610	3rd buoy-right (30248.5/49100.9) Mixing zone	8 alewife 1 johnny darter	190 24 Total 214
33609	3rd buoy-left (30249.1/49103.8) Mixing zone	1 alewife	24
33608	3rd buoy-center (30248.8/49100.9) Mixing zone	3 alewife	71
33607	4th buoy-right (30247.8/49099.9) Mixing zone	2 gizzard shad	48
33606	4th buoy-left (30248.1/49099.8) Mixing zone	1 gizzard shad	24
33605	4th buoy-center (30248.0/49099.9) Mixing zone	1 johnny darter 2 alewife	24 48 Total 71

APPENDIX 2 - F

Fish Capture Data - Drift Sample 85/08/08 - Night

Label #	Location (Loran grid)	Larval fish collected (length in mm)	Density (larvae/1000 m^3)
33675	1st buoy-center (30250.2/49103.5) Lake	15 alewife 2 johnny darter (both 6)	313 48 Total 405
33676	1st buoy-right (30250.3/49103.6) Lake	9 alewife 1 cyprinid	214 24 Total 238
33677	1st buoy-left (30250.2/49103.3) Lake	4 alewife (10,11) 1 johnny darter (6)	95 24 Total 119
33678	2nd buoy-center (30249.7/49103.5) Lake	4 alewife	95
33679	2nd buoy-right (30249.8/49103.5) Lake	6 alewife 2 johnny darter (4,5)	143 48 Total 191
33680	2nd buoy-left (30149.7/49103.2) Lake	4 alewife 1 gizzard shad 1 johnny darter	95 24 24 Total 143
33681	3rd buoy-center (30249.1/49103.8) Mixing zone	3 alewife 1 gizzard shad	71 24 Total 95

APPENDIX 2 - G

Fish Capture Data - Drift Sample 85/08/09 - Night

Label #	Location (Loran grid)	Larval fish collected (length in mm)	Density (larvae/1000 m^3)
31668	1st buoy-left	3 trout perch (4,2x6)	71
	(30250.1/49103.1)	2 smelt (both 13)	48
	Lake		Total 119
31667	1st buoy-right	1 alewife (4)	24
	(30250.1/49103.4)		
	Lake		
31666	1st buoy-center	2 trout perch (5,6)	48
	(30250.1/49103.1)	1 smelt (16)	24
	Lake	1 unidentified	24
			Total 95
31665	2nd buoy-left	0	----
	(30249.5/49102.8)		
	Lake		
31664	2nd buoy-right	5 alewife (16,7,7,4,?)	119
	(30249.5/49102.8)	4 trout perch (3x6,6.5)	95
	Lake		Total 214
31663	2nd buoy-center	0	----
	(30249.6/49102.9)		
	Lake		
31662	3rd buoy-right	5 g. shad (22,21,18,16)	119
	(30249.3/49103.0)	6 alewife	143
		1 johnny darter	24
	Mixing zone		Total 286
31661	3rd buoy-center	3 alewife (16,7,6)	71
	(30249.0/49103.1)		
	Mixing zone		
31660	4th buoy-right	3 alewife (7.5,7.0,4.5)	71
	(30249.6/49103.3)	2 johnny darter (6,5)	48
		2 gizzard shad (23,22)	48
	Mixing zone		Total 167
31659	4th buoy-left	0	---
	(30249.1/49103.3)		
	Mixing zone		
31658	4th buoy-center	12 g. shad (22,3x23,24)	286
	(30249.3/49103.4)	2 alewife	48
	Mixing zone		Total 333

APPENDIX 2 - H

Fish Capture Data - Drift Sample 85/08/12 - Night

Label #	Location (Loran grid)	Larval fish collected (length in mm)	Density (larvae/1000 m^3)
31700	1st buoy-center	3 alewife	71
	(30247.2/49102.8)	3 gizzard shad	71
	Lake		Total 124
31701	1st buoy-left	4 g. shad (23,21)	95
	(30247.3/49103.0)	3 alewife (2x22,21)	71
	Lake	1 trout perch	24
			Total 190
31702	1st buoy-right	11 g.shad (23,2x21,23)	261
	(30246.9/49102.4)	7 alewife (16,14)	167
	Lake		Total 429
31703	2nd buoy-center	12 g. shad (2x22,21,20)	286
	(30247.5/49102.5)	2 alewife (16,14)	48
	Mixing zone		Total 333
31704	2nd buoy-left	2 gizzard shad (23)	48
	(30248.0/49102.7)		
	Mixing zone		
31705	4th buoy-center	1 gizzard shad (23)	24
	(30247.5/49102.2)	1 alewife (5)	24
	Mixing zone		Total 48

APPENDIX 2 - I

Fish Capture Data - Drift Sample 85/08/13 - Night

Label #	Location (Loran grid)	Larval fish collected (length in mm)	Density (larvae/1000 m^3)
33811	1st buoy-center (30250.7/49103.2) Lake	1 alewife (16)	24
33810	1st buoy-left (30250.8/49103.2) Lake	3 alewife	71
31748	2nd buoy-left (30249.4/49102.9) Lake	0	—
33808	2nd buoy-center (30249.2/49102.9) Lake	1 alewife	24
31749	2nd buoy-right (30249.0/49103.0) Lake	6 alewife	143
31750	3rd buoy-center (30248.9/49102.1) Mixing zone	1 alewife	24
31710	3rd buoy-left (30248.8/49102.1) Mixing zone	1 unidentified	24
31709	3rd buoy-right (30248.9/49102.4) Mixing zone	1 alewife	24
31708	4th buoy-center (30248.6/49101.4) Mixing zone	4 alewife (6.5)	95
31707	4th buoy-left (30248.9/49101.6) Mixing zone	2 alewife	48
31706	4th buoy-right (30248.3/49101.2) Mixing zone	5 alewife 1 unidentified	119 24 Total 143

APPENDIX 2 - J

Fish Capture Data - Drift Sample 85/08/14 - Night

Label #	Location (Loran grid)	Larval fish collected (length in mm)	Density (larvae/1000 m^3)
33822	1st buoy-left (30249.9/49103.1) Lake	0	---
33823	1st buoy-center (30249.9/49103.5) Lake	1 alewife (16) 1 trout perch (6)	24 24 Total 48
33824	1st buoy-right (30249.9/49103.5) Lake	4 alewife (19,15,13,5)	96
33825	2nd buoy-left (30249.1/49102.9) Mixing zone	1 alewife	24
33826	2nd buoy-center (30248.8/49103.7) Mixing zone	0	----
33827	2nd buoy-right (30248.3/49102.6) Mixing zone	0	----
33828	3rd buoy-center (30248.6/49101.1) Mixing zone	0	----
33829	3rd buoy-right (30248.5/49101.4) Mixing zone	1 alewife (5)	24
33830	3rd buoy-left (30248.6/49100.7) Mixing zone	0	----

APPENDIX 2 - K

Discharge Larval Fish Collections Night 85/08/08 - 85/08/13

Date	Larval fish collected	Density (larvae/1000 m^3)
85/08/08	6 alewife 1 smelt	143 24 total 167
85/08/08	7 alewife 1 smelt	167 24 total 191
85/08/08	3 alewife	71
85/08/11	_____	_____
85/08/11	1 smelt	24
85/08/11	_____	_____
85/08/12	1 smelt	24
85/08/12	_____	_____
85/08/12	1 alewife	24
85/08/13	2 alewife	48
85/08/13	1 alewife	24
85/08/13	1 alewife	24

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